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Applied Engineering in Stifle Repairs

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A dog is sent out for a romp and returns limping, one rear leg drawn up. It does not improve over a period of time and the veterinarian diagnoses a torn cruciate ligament. Surgery is performed and within a few weeks the dog is back on all four legs. To the owner the procedure was successful, the dog can run around and the gait appears to be normal. For Gail Smith, V.M.D., Ph.D., this assessment is not enough. The assistant professor of orthopedic surgery at the Veterinary School of the University of Pennsylvania wants to find out whether surgery restored the stifle to maximum stability, ideally to the pre-injury state.

Dr. Smith currently is studying results of different surgical techniques used in cruciate ligament repair to determine which procedure comes closest to restoring the pre-injury conditions. He is conducting quantitative studies where he evaluates the repaired joints and compares them to the uninjured ones. The study is done in conjunction with the Sports Medicine Center at HUP; the measurements and tests are performed at the University of Medicine and Dentistry of New Jersey.

Dr. Smith holds an engineering degree in metallurgy and materials sciences and approaches the stifle joint and its repairs as a problem of loads, stresses, and function of materials. He is not content with exterior evidence and has designed the tests to measure the mechanical stability of the repaired joints. His limited testing has shown that repairs cannot return the stifle to its pre-injury state. "Despite the repairs done, a joint cannot be defined as normal after surgery," he explained. "The problem is that no material is as finely tuned as the original material, the anterior cruciate ligament. The best we can do at this time is to come close to the pre-injury stability."

That is a formidable task when one recognizes that the stifle joint presents a complex arrangement of bones, cartilage, ligaments, and muscles, organized in such a manner to permit articulation of the joint whenever the dog walks, runs, jumps, sits, or lies down. It is a masterpiece of construction where forces and counterforces keep the bones from slipping and sliding and permit an accurate, efficient gait.

Each of the many ligaments in the stifle joint has a special function. The two cruciate ligaments are arranged in the interior of the joint, crossing each other, connecting the femur and the tibia. One can think of them as crossed bindings holding the joint together internally, permitting only the hinge action needed for flexing the joint. The two ligaments are strong and composed of precisely arranged bundles of collagen fibers covered by a synovial membrane. The posterior cruciate ligament is not commonly injured; it is the anterior cruciate ligament which bears the brunt of the damage if the joint is used improperly. This occurs if the dog catches its foot, if it is hit sideways, or if it twists its leg with the full weight on the limb, very similar to the classic "football knee." Then the anterior cruciate ligament may tear, either partially or completely.

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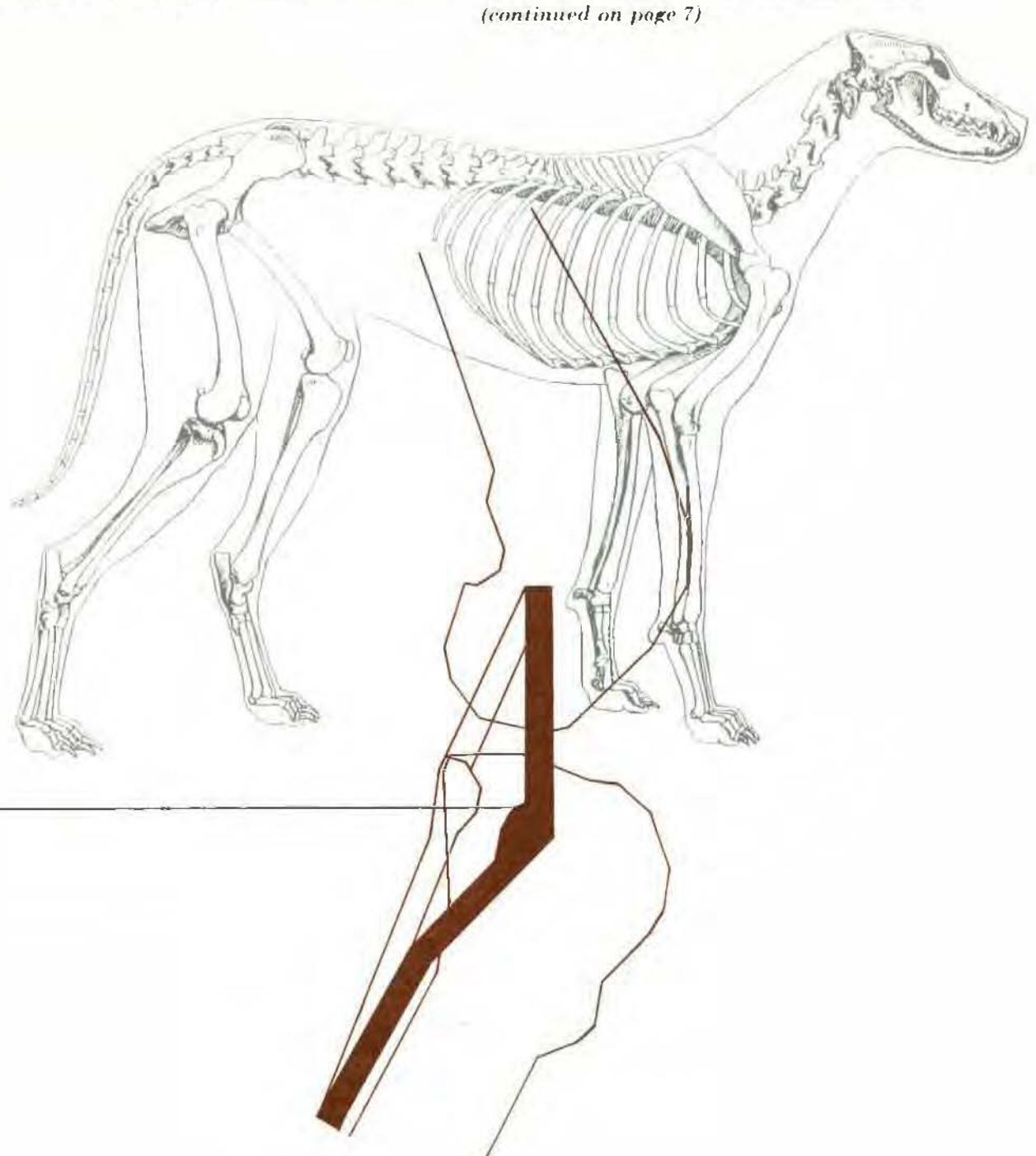

Anterior displacement (transposition) of the fibular head and attached lateral collateral ligament, places this ligament in an orientation to resist anterior drawer and internal rotation of the tibia on the femur.

prevent foot lesions and nesting straw is provided for the mating pairs.

Dr. Southam noted that similar research with woodchucks is being conducted at Cornell University, and there is a small colony at the Philadelphia Zoo. Dr. Blumberg is also working with domestic Pekin ducks, a species also found to carry the B-like virus, she said.

Other principals involved with hepatitis B virus and primary liver cancer research at the Fox Chase Institute include Dr. Jesse Summers, Dr. Irving Millman and Dr. W. Thomas London, all colleagues of Dr. Blumberg, who is the Institute's associate director of clinical research.

A graduate of Grinnell College in Iowa, with a B.A. in biology, Dr. Southam, formerly of Demarest, N.J., earned her D.V.M. from the Veterinary School of the University of Mexico, Mexico City. Her choice of Mexico was, in part, based on the fact that it was especially difficult for a non-resident to get into Penn in the 1970's. She did, however, complete her intership at Penn.

Before entering the University of Mexico, Dr. Southam had worked as a reproduction physiology technician. No stranger to animal colonies, she raised a colony of rhesus monkeys when she was employed by the Population Council in New York.

"I was always interested in animal models and have raised colonies of rats, rabbits, and monkeys. In fact, the breeding aspect of the woodchuck colony is what interested me in the Project," she said.

An outdoorswoman, Dr. Southam likes nothing better than to take off for a camping or skiing trip in her 1974 Kharmanghia, which she keeps mechanically well-tuned. From her Thornton home on Brinton Lake, Delaware County, she makes occasional house calls. Long term plans call for a full-time private practice.

For now, Dr. Southam enjoys her role in the Woodchuck Project and her quiet retreat in the woods. It's not uncommon for her to put in a 12-hour day, but she always finds time for a walk in the woods or a romp with her dog, who shares the premises with her along with four goats and the woodchuck pens.

Instead of grumbling about groundhog holes, it seems we owe the woodchuck a little respect in view of its sacrifice for the cause of science.

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Dr. Smith explained that it is rare when the only injured element of the joint is the anterior cruciate. In that case knee function is often regained without surgery as nature heals the injury by fibrous proliferation of the medial structure, the medial collateral ligament. This additional support compensates for the loss of the anterior cruciate. In most cases though other parts of the joint are also damaged and the natural healing process cannot overcome the pain and instability. Often the menisci are damaged and this interferes with their function as "centering devices" within the joint. Also, when the anterior cruciate ligament is torn, the "binding-like" effect ceases. The joint becomes loose and the tibia can move forward, sliding like a drawer along the joint tissue, it also can suddenly rotate. These movements irritate and erode the bone surfaces and cartilages, causing a painful inflammatory response and the development of extra bony tissue which further irritates the joint. Left untreated the condition continues to worsen and degenerative arthritis develops. As the joint thickens, movement may be impaired. To prevent these ongoing secondary changes, and to repair the initial injury, surgery can be performed.

The many surgical techniques used for the repair of a torn anterior cruciate ligament can be divided into two categories, intra articular repairs and extra articular repairs. In the first the surgeon removes the damaged ligament and replaces it with a graft, using either tissue taken from the dog or an artificial material. This procedure is quite successful and statistics show that seventy to ninety-five percent of the dogs appear to regain function of the joint. When using the extra articular technique, the surgeon stabilizes the joint by using muscles, tendons, and ligaments at the exterior of the joint and he tightens them in a manner to eliminate the joint instability. There is no attempt to replace the anterior cruciate ligament.

Dr. Smith favors the latter approach. He has developed a technique to achieve joint stability by altering the stresses and functions of two ligaments in the joint by rerouting one. He starts his procedure with the lateral collateral ligament which mainly connects the fibula with the femur, but also has a fibrous connection to the tibia. By severing this connection and moving the fibula forward onto the tibia, he changes the angle of attachment of the lateral collateral ligament, creating a resultant force which tightens the joint. This causes the medial collateral ligament, which joins the femur and the tibia on the other side of the joint, to alter its function. It now opposes and stabilizes the surgically induced forces of the lateral collateral ligament. Through this procedure, Dr. Smith creates two exterior bindings which give the joint stability and which prevent the forward and rotational movement of the tibia.

He has found that the point of surgical attachment of the lateral collateral ligament varies from dog to dog due to the stretch factor of each individual ligament and inherent anatomical variation. The object of the surgery is to obtain maximum tightening of the joint and this is assessed for each individual during surgery. Smith also found, that, contrary to earlier opinion, it is important not to remove the menisci completely but to salvage or *partially* excise them and leave them in place because they act as centering devices in the joint. In his studies, Dr. Smith found that this surgery, "fibular head transposition," provides the greatest amount of joint stability when compared to other procedures, because the fibula is moved over by the force of the altered course of the ligament. His measurements show that the drawer effect, where the tibia can be moved forward, is smaller than after other surgical techniques used to repair the injury.

Because cruciate ligament injury is so common, this is good news to dog owners. Dr. Smith explained that patients can be divided into two groups: the young athletic dog which overdoes it or uses the leg in the wrong way, and the older, often overweight dog. In the latter, it appears that the ligament weakens due to degeneration and just gives way. This problem is aggrevated by patellar luxation. Dr. Smith feels that dogs which have a luxated patella are predisposed to anterior cruciate ligament rupture and should be considered as surgical candidates for patellar relocation as a preventative measure, especially if middle aged, overweight, and unfit.

The tests Dr. Smith has conducted show that surgery, at the present time, cannot return an injured stifle to its pre-injury stability. Though he has found that by applying engineering principles to the construction and materials of the joint, a close approximation of such stability is possible for the injured dog. The studies help to determine the limits of natural and artificial materials and point the way to better surgical techniques, not only for dogs, but also for people who, like their four-footed friends, are quite prone to tearing the cruciate ligament.